AD-A263 571

PL-TR-93-2022

ELECTRODYNAMICS OF THE DAYSIDE CLEFT REGION BASED ON GROUND OBSERVATIONS AT SVALBARD

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20 January 1993

Final Report
December 1991-January 1992

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PHILLIPS LABORATORY
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HANSCOM AIR FORCE BASE, MA 01731-3010

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
20 January 1993

3. REPORT TYPE AND DATES COVERED
Final Report (December 1991 - January 92)

4. TITLE AND SUBTITLE
Electrodynamics of the Dayside Cleft Region Based on Ground Observations at Svalbard

5. FUNDING NUMBERS
PE 61102F
PR 2310 TA G9 WU AN

Contract AFOSR-90-0082

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Phillips Laboratory
29 Randolph Road
Hanscom AFB, MA 01731-3010

Contract Manager: Edward Weber/GPIS

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
PL-TR-93-2022

11. SUPPLEMENTARY NOTES
This is a continuation and extension of scientific reports number 1 and 2.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Based on extensive, diagnostic ground observations in the Svalbard region (mainly at Ny Ålesund at 76° Λ) together with simultaneous, coordinated measurements from Greenland and Heiss Island - spanning ~ 4 hours in magnetic local time, - together with the EISCAT radars as well as DMSP satellite-recordings, essential information on the dynamics of the dayside cleft and polar cap region (auroral, ionospheric and electric field) have been obtained. This is an important prerequisite to the understanding of the physics of the dayside boundary layers.

Several papers have been presented and many lectures given related to this program. Possible generation mechanisms of dayside cusp/cleft auroras including magnetic merging, external pressure pulses, Kelvin-Helmholtz-instabilities, and dynamo processes by intruding plasma elements are discussed. To determine the characteristic auroral signatures of these boundary layer processes is a major objective of these studies.

14. SUBJECT TERMS
Ground based observations
Dayside aurora
Cusp
Cleft/LLBL
Polar Ionosphere
Boundary regions/processes

15. NUMBER OF PAGES
16

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

CONTENTS

1. INTRODUCTION

Svalbard is the Arctic archipelago between 10° and 35° East and 74° and 81° North. The geomagnetic latitude spans from approximately 71° to 77° North. The high geographic latitude at geomagnetic latitudes well above 70°, makes Svalbard a unique place for studies of dayside aurora within the cleft, cusp and polar cap, and processes related to magnetospheric boundaries. Its conjugacy to stations in Antarctica makes Svalbard even more attractive.

The observatories at Ny Ålesund and Longyearbyen are the master stations in the Svalbard network which also includes field stations at Hopen, Hornsund, Bjørnøya, Jan Mayen, and since October -92 also Danmarkshavn, Greenland. The latitude separation between neighbour stations ranges within 110-250 km. The core instruments are meridian scanning photometers, optical imagers at different wavelengths, magnetometers and riometers. A list of the instrumentation at the different stations as well as geomagnetic and geographic coordinates for these sites were included in the First Annual Technical Report. Since December 1991 an advanced digital ionosonde together with satellite scintillation receivers have been installed at Ny Ålesund. The EISCAT VHF and UHF radars at Tromsø have been coordinated with our Svalbard observations in addition to simultaneous, overhead recordings by the DMSP satellites.

Based on extensive, diagnostic ground observations in the Svalbard region (mainly at Ny Ålesund at 76° Λ) together with simultaneous, coordinated measurements from Greenland and Heiss Island - spanning ~ 4 hours in magnetic local time, - together with the EISCAT radars as well as DMSP satellite-recordings, essential information on the dynamics of the dayside cleft and polar cap region (auroral, ionospheric and electric field) have been obtained. This is an important prerequisite to the understanding of the physics of the dayside boundary layers.

Several papers have been presented and many lectures given related to this program. Possible generation mechanisms of dayside cusp/cleft auroras including magnetic merging, external pressure pulses, Kelvin-Helmholtz-instabilities, and dynamo processes powered by intruding

plasma elements are discussed. To determine the characteristic auroral signatures of these boundary layer processes is a major objective of these studies.

OBSERVATIONS AND THE RESEARCH PROGRAMME AT SVALBARD DURING THIS REPORT PERIOD

The observation programme in this joint cooperation between Ionospheric Effects Division, at Phillips Laboratory, (Coordinator Dr. E. Weber), Hanscom AFB, Bedford, MA and The Group of Cosmical Physics at the University of Oslo, is concentrated on the electrodynamics and spectral properties of the dayside cusp, cleft and cap auroras. The main measurements are carried out with multichannel, meridian scanning photometers and advanced, optical imagers at different wavelengths.

During the contract period the following "campaigns" - where our Svalbard optical observations have been of prime importance - *have been carried out:*

a. A special EISCAT selected program for comparing ion drifts and the dynamics of dayside aurora (December 1991 and January -92).
b. EISCAT - common program (CP4); Dec. and Jan. 1992.
c. Selected event studies including coordinated observations from the satellites DMSP, F-7, 8, 9, and 10. (Particularly during the days 2. December -91 and 6., 7., 8., and 12. January 1992 we have selected some very interesting cases).

The enclosed copy of the Observation Protocol (Appendix I) includes the most interesting dayside auroral events. Some of these data have already been studied in detail and compared with other relevant space and ground based observations (cf. Publication list). Our conclusion is quite clear, namely: Coordinated ground measurements and in-situ observations from satellites in polar orbit are essential for understanding solar wind - magnetosphere - ionosphere coupling.

The optical auroral data are extensively used as a basis for the study of the dynamics and fine structures of the magnetopause boundary layers. A wide range of spatial scales of optical events as well as their internal structure is observed. Of main importance in this respect is the location of the various optical events in relation to the major particle precipitation boundaries and the large-scale ionospheric ion drift pattern. However, some features of the aurora may not in all respect point directly to the boundaries and separatrices of importance to the study of the magnetosphere. A careful study of coordinated satellite and ground-based data is therefore required in order to reveal the more subtle signs of the boundary layers.

Coordinated ground- and satellite observations are required in order to study the connection between the dayside forms, the acceleration regions and the region of plasma entry. The problem of pulsed magnetopause reconnection, flux transfer events and their manifestations at different levels in the magnetosphere and in the ionosphere is still a central subject.

As seen from the enclosed list of publications and lectures given, the Group members have been very active during the report period. Ground based auroral structures and dynamics from Svalbard have been compared with simultaneous measurements of energetic electron and ion precipitation as well as horizontal plasma drifts. Brightening and movements (sun and anti-sunward) of certain discrete auroral forms seem to be connected with external dynamic pressure variations, associated magnetopause perturbations and fundamental modes of magnetosphere - ionosphere coupling, such as kinetic Alfvén waves.

A few other findings will be briefly summarized:

The observed north-westward motion of auroral forms in the prenoon sector is typical for periods of positive IMF B_Y, whereas auroral events associated with negative IMF B_Y are moving northeastward in the midday and early post-noon sector. These optical events mostly appear as a brightening of the 630.0 nm aurora near the poleward boundary of the persistent cleft/LLBL precipitation at the boundary of the field-of-view of the TV camera. This phenomenon is a characteristic feature of the near cusp region during periods of expanded oval/enhanced polar cap convection.

Special attention has also been given to the height distribution of dayside auroras and the relation between cusp/cleft emissions and net downward energy flux. It is instructive to compare optical aurora and particle precipitation because these two quantities should be proportional, if the dayside aurora is caused by electron impact. The main findings for quiet events (i.e. the 630 nm emission dominate) indicate 1) that some dayside auroras are emitted at significantly higher altitudes than normally assumed, and 2) that both thermal electron excitation and dissociative recombination may be important additional excitation mechanisms for the red cusp/cleft aurora.

The question of signatures in the dayside aurora related to solar wind - magnetosphere coupling modes has been in focus in recent years. Auroral precipitation signatures of dayside magnetosphere boundary layers have been studied extensively by using data from polar orbiting satellites. Automatic classification schemes have been applied to the DMSP-precipitation data, in order to statistically identify the particle source regions, such as the central plasma sheet, the boundary plasma sheet, the low latitude boundary layer, the cusp, the plasma mantle and polar rain. However, our optical observations may need alternative interpretations. Within a few years, we hope to have a statistical significant data base for identification of the different dayside regions based on their optical signatures.

Several possible generation mechanisms for auroral forms, occurring near magnetic noon, during different IMF conditions are possible. (cf. Introduction). These include magnetic merging poleward of the cusp, variations in the solar wind pressure, Kelvin-Helmholtz instabilities and dynamo processes in the low - and high-latitude boundary layers of the magnetosphere, powered by intruding plasma elements.

A class of dayside auroral forms is consistent with essential features of the predicted ionospheric signatures of sequences of transient and patchy magnetopause merging events. However, some features of the observations, such as the long decay phase sometimes observed may not be easily explained by the presently available models. Due to the present limited understanding of ionosphere - magnetosphere field line mapping there is some uncertainty on whether auroral events, associated with "mantle" precipitation poleward of the continuous cleft arc, are coupled to the high-latitude boundary layer or the low-latitude

boundary layer. This is a critical point for the identification of the solar wind - magnetosphere coupling mode involved, i.e. mergir . or viscous process. One of the most specific properties of the merging process is the associated zonal ionospheric ion drift related to the IMF P polarity. The presently available data indicate that a similar motion pattern exists for the optical events. Thus, better statistics on the east-west motion of the auroral events in relation to IMF B_Y will be a crucial test of the present interpretation interms of magnetic merging.

PROGRAM FOR 1993

Even if this is The Final Technical Report for Grant No AFOSR - 90-0082, the cooperation with the Ionospheric Effects Division at Phillips Laboratory, Hanscom AFB, Mass. will continue both formally (via Grant No) and in practical, joint cooperation. Thus, during the January - 1993 campaign at Ny Ålesund, several scientists from Phillips Laboratory (headed by Dr. E.J. Weber and Mr. Jürgen Buchau) actively participated. Also during this campaign where the continuous ground observations were closely coordinated with simultaneous EISCAT recordings as well as overhead, DMSP satellite-measurements.

During the autumn (November -93 and/or January -94) the Oslo-group will launch a rocket from Andøya Rocket Range to study pulsating auroras. The in-situ measurements are carried out by several complementary diagnostics, including six separated photometers. A special campaign is planned in connection with this rocket launch.

Other, further studies will also be extended to include nightside auroral phenomena inside the polar cap. In addition, coordination with the new, ionospheric satellite FREJA is also planned.

During the autumn of -92, we installed a multichannel, meridian scanning photometer at Danmarkshavn, Greenland. This is a high latitude Danish Auroral Station very conveniently located in relation to Ny Ålesund.

We are also continuously working to improve the observation techniques and the routines for data reduction. A combined hardware/software system for analysis of TV images has thus been developed. We are still working on a new data logging system with modem connection to our and other laboratories. This will provide more direct access to the optical and magnetic data.

During the winter 1991/92, an advanced digital ionosonde (with large antennas) together with satellite scintillation receivers was installed and are now in continuous operation at Ny Ålesund. Both these instruments come from The Ionospheric Effect Division at Phillips Laboratory, Hanscom AFB. Jürgen Buchau is responsible for the ionosonde while Santi Basu Controls the scintillation measurements. Both these instruments are part of a larger net, with several identical set-ups in Greenland. By combining these new observations with existing instrumentations, it is possible to study the electron density in the polar ionosphere in great details, as well as the dynamics of the ionosphere including the drift of ionization patches. From detailed spectral studies of the scintillation measurements it is possible to determine which instability mechanism is responsible for the irregularities in the polar cusp and cap. These new parameters will be of great importance for understanding the physics of the boundary layer processes. The results obtained will be compared with existing theoretical models. An important part is the understanding of the mechanisms responsible for the formation of polar cap F-layer patches.

Department of Physics at the University of Oslo is responsible for the operation of these instruments.

EXCHANGE OF SCIENTISTS BETWEEN THE TWO INSTITUTIONS

We have had a close contract with the program manager for this contract, Dr. Edward J. Weber, during the whole period. Both Dr. Weber and Mr. J. Buchau have visited us in Oslo during the last year.

The project scientist spent two weeks at Phillips Laboratory (December 1992). Dr. H. Carlson, the Deputy Chief Scientist at Ionospheric Effects Division, Hanscom AFB, visited us in Oslo in May. Dr. W.F. Denig from the Space Plasma and Field Branch, Phillips Laboratory, spent two months (August and September -92) in our group working with the Svalbard data. That visit was a very important contribution to strengthening the cooperation between the two groups. One of the young members of our Group - research assistant Jøran Moen - spent one month (August 1992) at Ionospheric Effects Division, Phillips Laboratory.

CONCLUSION

The cooperation with the scientists at the Phillips Laboratory, Geophysics Directorate have been both fruitful and enjoyable. This is clearly demonstrated by our publication list for 1992 (cf. page x). Without the financial support via this Grant it would not been possible for our Group to cover each winter period with continuous auroral observations at Svalbard, neither likely that we could have sent graduate students to the Phillips Laboratory.

The new Grant (F 49620-92-J-0507) will allow us to continue and even extend the described cooperation. The new parameters (scintillations and ionospheric electron densities as well as drifts) should be of great importance for understanding the physics of the dayside ionosphere and the magnetospheric boundary layer processes. In particular, we should learn more about the generation, characteristics and the drift of the polar cap F-region patches.

PUBLICATIONS/REPORTS

The following papers/reports, pertinent to this contract, have been published during the contract period:

1. Carlson, H. and A. Egeland; The Aurora and the Polar Ionosphere. Chapter 14 to a new textbook in Space Physics (Kivelson and Russell, eds.), Cambridge Press.

2. Denig, W.F., W.J. Burke, N.C. Maynard, F.J. Rich, B. Jacobsen, P.E. Sandholt, A. Egeland, S. Leontjev, and V.G. Vorobjev: Ionospheric signatures of dayside magnetopause transients: A case study using satellite and ground measurements, J. Geophys. Res, in press 1992.

3. Egeland, A., W.J. Burke, N.C. Maynard, E.M. Basinska, J.A. Slavin, J.D. Winningham, and C.S. Deehr; Prenoon Ground and Satellite Observations near the Time of a Sudden Storm Commencement, J. Geophys. Res., in press, 1992.

4. Egeland, A., H.C. Carlson, W.F. Denig, K. Fukui, E. Weber: Day-side Auroral Signatures Based on Simultaneous, Coordinated Observations at Svalbard and Greenland, IEEE Transactions on Plasma Science; Third Special Issue, in press 1992.

5. Moen, J., W.J. Burke, and P.E. Sandholt, A rotating, midday auroral event with northward IMF, J. Geophys. Res., in press 1992.

6. Moen, J., P.E. Sandholt, M. Lockwood, A. Egeland, and K. Fukui, Multiple, discrete arcs on sunward convecting field lines in the 14 - 15 MLT region, J. Geophys. Res., submitted des. 1992.

7. Pudovkin, M.I., S.A. Zaitseva, P.E. Sandholt, and A. Egeland: Dynamics of aurora in the cusp region and characteristics of magnetic reconnection at the magnetopause. Planet. Space Sci., 40, 879, 1992.

8. Sandholt, P.E. and P.T. Newell: Ground and satellite observations of an auroral event at the cusp/cleft equatorward boundary, J. Geophys. Res., 97, 8685, 1992.

9. Sandholt, P.E., M. Lockwood, W.F. Denig, R.C. Elphic, and S. Leontjev: Dynamical auroral structure in the vicinity of the polar cusp: Multipoint observations during southward and northward IMF, Ann. Geophys., 10, 483, 1992.

10. Sandholt, P.E., Dayside auroral activity and magnetospheric transient events, in European Space Agency Spec. Publ., Noordwijk, The Netherlands, 1992, ESA SP-335, pp. 83-88.

11. Sandholt, P.E., J. Moen and D. Opsvik, Periodic auroral events at the midday polar cap boundary: Implications for solar wind-magnetosphere coupling, Geophys. Res. Lett., 19, 1223-1226, 1992.

12. Sandholt, P.E., J. Moen, D. Opsvik, W.F. Denig and W.J. Burke, Auroral event sequence at the dayside polar cap boundary: Signature of time-varying solar wind - magnetosphere - ionosphere coupling, Adv. Space. Res., in press 1992.

13. Sandholt, P.E., J. Moen, A. Rudland, D. Opsvik, W.F. Denig, and T. Hansen, Auroral event sequences at the dayside polar cap boundary for positive and negative IMF B_Y, J. Geophys. Res., in press, 1992.

14. Sandholt, P.E., Magnetopause plasma transients: Mapping into the auroral ionosphere, IEEE Transactions on Plasma Science, in press, 1992.

15. Sandholt, P.E., W.F. Denig, J. Moen, D. Opsvik, A. Egeland, and E. Friis-Christensen. Auroral transients at the dayside polar cap boundary in relation to cusp and cleft/LLBL precipitation and convection, Geophys. Res. Lett., submitted December 1992.

16. Sandholt, P.E., C.J. Farrugia, and L. Burlaga, Auroral activity in the postnoon sector during interplanetary magnetic cloud passage with large negative B_Y: Interpretation in terms of combined viscous coupling and magnetic reconnection, J. Geophys. Res., submitted 1993.

17. Yagordkina, O.I., V.G. Vorobjev, S.V. Leontjev, P.E. Sandholt and A. Egeland, Bursts of geomagnetic pulsations and their relationship with dayside auroral forms, Planet. Space Sci., 40, 1303 - 1309, 1992.

CONFERENCE CONTRIBUTIONS AND LECTURES:

Lectures and papers based on the cusp/cleft/cap observations at Svalbard (pertinent to this contract) were during 1992 presented at the following international meetings:

a) The AGU Fall Meeting, San Fransisco, Cal, December 7. - 11.

b) International Substorm Conference, Kiruna, Sweden, March 23 - 27.

c) World Space Congress (Cospar Meeting), Washington D.C., August 28. - Sept. 5.

d) The European Optical Society Meeting, Kiruna, Sweden, August 10. - 15.

e) Phillips Laboratory, Hanscom AFB, Dec. 16.

APPENDIX I:

NY ÅLESUND OPTICAL CAMPAIGN
NOVEMBER/DECEMBER -91
JANUARY 1992

Day	Time	Auroral characteristics
28.11.91	0715-1600 UT	All instruments recording, MSP (photometers in scanning mode), ISIT, HTH TV cameras, all-sky film camera.
	1117 UT	Multiple arc. s. zenith
	1430-1500 UT	Moving polar arc
29.11	0605-2400 UT	Partly cloudy
30.11	0502-1539 UT	
	0715 UT	Active aurora in zenith
1.12	0540-	All instruments in operation
	0800 UT	Interesting aurora in north
	0940	Multiple arcs s. zenith
2.12	0500-	
	0830-100 UT	Periodic auroral events at cusp/cleft poleward boundary. Strong red line (7-8 kR). Magnificent!
3.12	0515-1620 UT	
	0700-0800	Active boundary layer aurora
	0830-0930	Poleward moving events
	~1300	Magnificent aurora, multiple arcs near zenith (strong).
4.12	0454-1329 UT	Good weather
	0512 and 1112	Multiple arcs in zenith
5-6.12		Cloudy, snowing, windy
7.12		Rain!
8.12	0513-1100 UT	Clear sky, aurora in zenith and in south
	0655	Weak aurora in south
9.12		Snowing and windy.
	0730 UT	Start to clear up. Some problems with lens caps after mild weather.
15.12	0630 UT	Cloudy
	0833 UT	MSP recording, weak aurora
	0929 UT	Cloudy all over
27.12	0504 UT	Clear sky. MSP recording
	1115 UT	ISIT camera stopped, due to clouds in the south
28.12		Cloudy
29.12	0532 UT	Started ISIT and MSP, clear sky, aurora
	1130 UT	Stop recording
30.12	0517 UT	Started ISIT, MSP, clear sky and strong aurora
	1730 UT	Stopped ISIT and MSP
31.12		Cloudy and windy.
1.1	0400 UT	Cloudy
2.1	0512 UT	Start recording MSP
	0648 UT	Start recording ISIT camera. Cusp aurora in south, clear sky
	0730 UT	Clouds all over
3.1	0515 UT	Started MSP, partly clouded, no aurora
	1030 UT	Overcast, snowing

4.1	0500-1300 UT	Partly cloudy
	1300-	Clear sky and aurora
5.1	0500-	Clear sky and aurora
	0900 UT	Cusp near zenith
	1220 UT	Arcs in the north
	1730 UT	Stopped ISIT camera, MSP and film camera running all night
6.1	0515 UT	All instruments running. Red arc near souther horizon.
	0630-0730 UT	Weak cusp in the north
	1130-1200	Aurora near zenith
	1300-1600	Aurora in the south
	1740 UT	Stopped ISIT and HTH cameras. MSP is running all night
7.1	0511 UT	Clear sky. ISIT and HTH started
	0630	Nice aurora
	0925	Auroral activity, particularly in NE
	1125	Strong arc north of zenith
	1350	Auroral arc with "patch" on poleward side of it
	2009	Clear sky, aurora in south
8.1	0500 UT	HTH and ISIT tape started. MSP running all night Mostly clear sky
	0820 UT	Some clouds
	0930	Strong cusp in the south
	1000	"Cusp" moving northward
	1010-1012	Poleward drifting form
	1030	Weak aurora in south
	1455	Stopped recording, clouds
9.1	0513 UT	Started MSP, some thin clouds
	0725	Arc near zenith
	0800-1200	Hazy. Recording all night, partly cloudy, weak or no aurora
10.1	0450 UT	Instruments started, MSP running all night
	0735	Much clouds
	0915	Mostly clear sky, cusp in south, forms moving northward, repeat 10 min. later
	1015 UT	Strong arc in zenith
	1945	Some aurora
11.1	0504 UT	Started ISIT, HTH camera, MSP running all night. Clear sky
	1100 UT	Stop ISIT camera (scattered light increasing). Weak aurora
	1325 UT	Stop HTH camera
	1705	Clear sky, weak aurora
	2155	Started film camera. Clear sky. Weak aurora
12.1	0500 UT	Started ISIT, HTH. Clear sky, some aurora in south
	0800	Great aurora, poleward motions. Strong arc in zenith
	0930 UT	Very sharp red arc. moon coming up. Stop film camera
	1110 UT	Thin clouds, otherwise clear. Strong arc in south
	1305	Cloudy, stopped ISIT camera
	1745	Stopped MSP.